

GROUNDWATER SOURCE CONTROLS AND ABATEMENT OF ACID MINE DRAINAGE AT ABANDONED MINED LAND SITES IN COLORADO₁

Kirstin Brown₂

Abstract. Current regulations pertaining to the treatment of acid mine drainage make it difficult to remediate acid mine drainage at inactive mine sites. Groundwater source controls are a viable method for remediation of acid mine drainage problems. Colorado's Abandoned Mined Land (AML) Program has been performing groundwater source control work at a number of mine sites for the past fifteen years successfully. The ultimate goal of groundwater source controls is to prevent the formation of acid mine drainage through diverting or altering the groundwater flow in underground mine workings. The Roy Pray Mine, the Mountain Queen Mine, the Columbus Mine, the Sound Democrat Mine, the Silver Queen Mine, the Vermillion Mine, the Dinero Tunnel, the Mary Murphy Mine, the London Extension Mine, the Pride of the West Mine, and the Wyoming Mine have all been evaluated for groundwater source controls by Colorado AML. All of the above listed sites demonstrate that groundwater source controls are a preferred method for acid mine drainage mitigation.

Additional Key Words: Roy Pray, Mountain Queen, Columbus, Sound Democrat, Silver Queen, Vermillion, Dinero Tunnel, Mary Murphy, London Extension, Pride of the West, Wyoming, passive treatment, active treatment, and mine reclamation.

₁Paper was presented at the 2006 National Association of Abandoned Mined Land Programs 28th Annual Conference, September 25-27, 2006, Billings MT.

₂Reclamation Specialist/Geologist, Division of Reclamation, Mining and Safety
1313 Sherman St., Rm 215, Denver, CO 80203.

Groundwater source controls are a viable method for remediation of acid mine drainage problems. Current regulations pertaining to the treatment of acid mine drainage make it difficult to remediate acid mine drainage problems at abandoned mine sites. Often times, passive treatment systems and surface source controls are used to circumvent the regulations that require rigorous maintenance and perpetual treatment of mine drainage. Groundwater source controls are pursued less frequently because they often require the rehabilitation of underground mine workings. Groundwater source controls differ from surface source controls because they attempt to manipulate the mine drainage flow paths from underground. Groundwater source controls have the following advantages over other reclamation options as they are generally permanent (or can be), require no maintenance, provide valuable information about the groundwater that can lead to more informed decisions on reclamation options, can be cheaper, and are more attractive than conventional treatment systems at the portal (less visibly impacting).

Groundwater source controls should be pursued only when surface source controls and passive treatment systems have already been evaluated. Surface source controls are usually pursued first because the access at the surface for water manipulation is simpler compared to underground. Backfilling shafts, closing mine openings, or rerouting surface waters that connect to mine workings with acid mine drainage problems are examples of surface source controls. Passive treatment systems, such as wetlands and limestone channels, are usually evaluated in the beginning as well, but passive systems are not a viable reclamation method at many sites due to water chemistry and or environmental concerns (elevation, space constraints). Typically a mine is considered for groundwater source controls when the mine drainage effluent has a high concentration of metals and a relatively high pH. This mine water chemistry suggests that there is relatively small amount of contaminated water mixing with clean water inflows. This small input of contaminated water may be isolated easily or redirected from becoming contaminated.

Site access issues create another reason to pursue source controls as opposed to treatment systems at the portal. Many mine sites in Colorado are at high elevations or in rugged terrain. Maintenance of some sites is next to impossible, so groundwater source controls and their lack of required maintenance become an attractive reclamation option.

Mine workings have a tendency to collapse and usually have unstable ground conditions. Safety is a priority in determining the eligibility of a site for groundwater source controls. Site conditions have to be conducive to underground rehabilitation before underground reconnaissance and water sampling of the mine drainage. Colorado Abandoned Mined Program (AML) has been contracted by various governmental agencies to perform underground construction work and reconnaissance because of their expertise in underground mining. Groundwater source controls is the best reclamation option at many sites, but safety considerations must take precedence over continued underground construction.

The Colorado AML Program has been pursuing groundwater source controls at a number of mine sites for the past fifteen years. During this pursuit, Colorado AML has received funding from other governmental agencies, academic institutions, and non-profit organizations to perform studies and construction work. Colorado AML's ultimate goal of groundwater source controls is to divert mine waters and prevent contamination. A secondary and more cost effective effort is to isolate contaminated waters from clean water inflows or redirect flow paths to prevent further contamination of sensitive areas. The goal of preventing acid mine drainage altogether has not been achieved yet, but Colorado AML has successfully isolated contaminated waters from clean water inflows and redirected flow paths. However, at some sites, groundwater source control work has yielded little prevention or redirection of mine waters, but has benefited the mine site by providing new information about groundwater and acid mine drainage interactions. The new information then leads to more informed decisions about other site reclamation options. The Roy Pray Mine, the Mountain Queen Mine, the Columbus Mine, the Sound Democrat Mine, the Silver Queen Mine, the Vermillion Mine, the Dinero Tunnel, the Mary Murphy Mine, the London Extension Mine, the Pride of the West Mine and the Wyoming Mine have all been evaluated for groundwater source controls by Colorado AML. Five of the above mentioned mine sites are described below. Groundwater source controls were met with varying degrees of success at these mine sites. The pursuit of groundwater source controls has lead to positive reclamation options or actions at all of the above named mine sites.

At the Dinero Tunnel, located near Leadville, Colorado, the Bureau of Land Management (BLM) and the Colorado AML program are pursuing groundwater source controls. The ultimate goal at this site was to find and isolate distinct contaminated inflows into the tunnel to prevent or redirect contamination at the portal. After four years of construction work, the goal of isolating distinct inflows of highly contaminated water was abandoned due to escalating obstacles to rehabilitation and exploration. Project work at this site halted when a cave-in, located 2,000 feet beyond the portal, that is 150 feet long, fills the mine void to the roof, and is too expensive to remove from the tunnel. Although the ultimate goal of isolating flows deep within the Dinero Mine workings was not achieved, valuable information was gathered about the geology, structure, mine workings, and hydrology of the tunnel. The information gathered from underground investigations has helped to make decisions on remedial actions for the mine drainage. The BLM prepared an Engineering Evaluation and Cost Analysis to outline the preferred alternatives to reclaim the Dinero Tunnel site. The BLM's preferred alternative for reclamation of the mine drainage is a hydrologic bulkhead seal with a valve. The proposed bulkhead seal location is located 1,250 feet beyond the portal, an area with enough groundcover and minimal faults and fractures. The bulkhead will be placed at the most appropriate location because groundwater source controls rehabilitated the mine workings far enough beyond the portal to allow for more informed decisions on the preferred remedial actions.



Figure 1. Dinero Tunnel cave-in at 2,000 feet beyond the portal.



Figure 2. Mining equipment at the Dinero Tunnel portal.

Groundwater source controls have been pursued at the Mary Murphy Mine, located near Buena Vista, Colorado, for the past ten years. The Mary Murphy project is a cooperative project with many sponsors, including the Colorado AML program. Numerous levels of the Mary Murphy Mine have been rehabilitated and investigated through funding from the Environmental Protection Agency. Water samples and flows have been taken from varying levels of the mine. In 1998 Colorado AML reopened the 1400 level of the mine and found a stream of water entering from a stope that contributed up to 85% of the total metals loading seen at the portal and comprised only 5% of the flow. This stope was used to demonstrate how flow could be redirected in a mine to



Figure 3. Jeff Graves water sampling at the Mary Murphy Mine in spring 2004.

change water quality conditions at the portal. The redirection of this flow minimized the metals load reaching Pomeroy Gulch and restored over two miles of stream. The Mary Murphy Mine project has successfully shown that groundwater source controls can alter the flow of mine waters to prevent contamination in environmentally sensitive areas. Cooperation with universities at the Mary Murphy site has also enhanced the academic communities' knowledge of mine pools and groundwater flow in high altitude environments. Work at the Mary Murphy Mine continues today. Water sampling is taking place and other levels of the mine are being investigated to assess potential for other groundwater source controls throughout the mine.

Groundwater source controls have also been effective at the London Extension Mine, located near Alma, Colorado. The London Extension Mine site is a high elevation mine site where access in the winter is limited. The London Extension Mine's underground workings were evaluated for groundwater source control work in 1993 by Colorado AML. After exploration work was completed, it was determined that a low

volume (approximately 5%) of mine inflow contributes roughly 90% of the metals contamination at the portal. This small contaminated flow could easily be isolated and



pipied to the surface for treatment. Even though the untreated mine drainage would exceed stream standards, the segregation would have resulted in a significant improvement in water quality. In 1997, the Colorado Department of Public Health and Environment persuaded the owner to accept a permit to treat the entire drainage from the London Extension Tunnel. The Colorado AML program built a small active neutralization treatment plant in 1997 to treat all of the mine drainage. The London Extension Mine is a good example of how groundwater source controls can find and isolate small inflows of contaminated waters and pipe them to the surface for lower cost treatment.

Figure 4. Piping contaminated water at the London Extension Mine.

The Pride of the West Mine near Silverton, Colorado was investigated to determine sources of zinc in the mine drainage. Approximately 40% of the contaminated flow was found to come from underground core holes drilled in the ribs and floor of the mine. These core holes are planned to be sealed this summer to eliminate a portion of the contaminated flow. The Pride of the West Mine will demonstrate how contaminated inflows can be prevented from entering the mine, lessening the impacts of mine drainage at the portal.

Groundwater source controls are being investigated at the Wyoming Mine site, near Lake City, Colorado because they are the only viable reclamation option available. The Wyoming Mine site is located at 13,000 feet and has no driving access. Initially surface source controls were installed. The two shafts on the surface that connect to the mine workings were sealed, thus eliminating water infiltration into mine openings and preventing further leaching of acid-forming materials. Passive treatment systems were also evaluated and would be difficult to install due to a lack of driving access and high elevation. Currently, there is no access to the underground workings to perform groundwater source controls. Underground rehabilitation of a caved portal was attempted in 2005, but work halted when an iron-cemented cave-in was encountered just inside the portal. The project was abandoned for the year because suitable equipment to remove the plug was not on-site and snow began to fall. Groundwater source controls were selected as the most suitable remedial action at the Wyoming Mine site due to the high elevation and lack of access. Groundwater source controls are the only feasible reclamation option at the Wyoming Mine site because all other reclamation options have been exhausted.



Figure 5. Historic mining equipment at the Wyoming.



Figure 6. Helicopter access at the Wyoming Mine.

Groundwater source controls are an under-utilized reclamation option for the remediation of acid mine drainage. They often offer lower cost, long term solutions for sustainable reclamation. Only a few states, governmental agencies, and institutions pursue this reclamation option. Groundwater source controls are leading to better understandings of groundwater interactions with mine drainage. The pursuit of groundwater source controls has lead to more permanent solutions, cheaper treatment alternatives, and installation of the most appropriate remedial actions. Colorado AML's projects demonstrate the usefulness of groundwater source controls. All of Colorado AML's projects benefited from groundwater source control work. The Dinero Tunnel work lead to a more informed decision on the bulkhead preferred alternative for reclamation. Mary Murphy Mine work lead to a demonstration of mine drainage segregation to divert water from exiting the portal and rehabilitated a two mile stretch of stream in an environmentally sensitive area. Work at the London Extension Mine showed that segregation of mine drainage could lead to lower cost treatment options with a treatment plant at the portal. The Pride of America Mine will demonstrate how contaminated inflows can be prevented from entering mine workings. Finally, work at the Wyoming Mine has demonstrated that in some cases, groundwater source controls are the only option available for remediation of acid mine drainage. Groundwater source controls can and should be utilized more often. The benefits of obtaining groundwater source controls are permanent solutions to acid mine drainage problems.

Acknowledgements

The Colorado Division of Reclamation, Mining and Safety, Abandoned Mined Land Program has received funding to perform groundwater source control work from the Environmental Protection Agency's Clean Water Act Section 319 funds, the Bureau of Land Management, United States Forest Service, Colorado Department of Public

Health and Environment, county agencies, and other governmental agencies. Construction and engineering work was performed alongside many contractors within the State of Colorado including: Frontier Environmental, Mining and Environmental Services, and John Abel. Many watershed groups have also contributed to groundwater source control projects including: Animas River Stakeholder's Group, Lake Fork of the Gunnison Watershed Group, Lake Fork of the Arkansas Watershed Group, Upper Arkansas Watershed Group, and Willow Creek Watershed Group. Colorado University, the Colorado School of Mines, Colorado Mountain College, Mesa State and Colorado State University all contributed to research on groundwater source controls.

References

- Ford, K. (BLM) 2006. Draft Final: Removal Site Inspection and Engineering Evaluation and Cost Analysis (EE/CA), Dinero Tunnel Acid Mine Drainage, Lake County, Colorado. Report prepared by the Bureau of Land Management for public review.
- Stover, B. K. (CDMG) 1997. Chalk Creek Project: Report on Results of Investigation, Mary Murphy Mine-Groundwater Hydrology Characterization Study, Chaffee County, Colorado. Report prepared by the Colorado Abandoned Mined Land Program.
- Stover, B. K. (CDMG) 2000. A Groundwater Source-controls Approach for Reducing or Eliminating Metals Loading in Discharge from the Inactive Mary Murphy Gold Mine, Chaffee County, Colorado. Report prepared by the Colorado Abandoned Mined Land Program.
- Wireman, M. (EPA) 2006. Hydrogeologic Characterization of Ground Waters, Mine Pools, and the Leadville Mine Drainage Tunnel, Leadville, Colorado. Paper presented at the 7th International Conference on Acid Rock Drainage (ICARD).